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Population characteristics of the abalone *Haliotis roei* on intertidal platforms in the Perth metropolitan area

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ABSTRACT

Basic population characteristics of the commercial abalone species *Haliotis roei* are compared on a heavily fished intertidal platform and a platform with no fishing pressure. Seasonal and annual variations in population density were large on both platforms, though densities were lower on the fished platform (Trigg) than the unfished area (Waterman). Most abalone at Waterman were adults of 2+ years (>60 mm), while few animals of this size occurred at Trigg. There were not sufficient adults at Trigg for reproduction on the platform to replenish the population, and it is postulated that replenishment comes from larvae originating from adjacent platforms. A subtidal rock with an unfished population of *H. roei* recovered at a rate of only about 10% per year, suggesting that heavily overfished populations would recover slowly, if at all.

INTRODUCTION

Little is known of the population characteristics of the abalone *Haliotis roei* Gray. General ecology of the species in South Australia has been discussed by Shepherd (1973) and stocks were subsequently surveyed (Branden, 1983; Branden and Shepherd, 1982; 1984) in that state. The reproduction, feeding and growth of *H. roei* in Western Australia has been examined by Wells and Keesing (1989) and Keesing and Wells (1989), but there is no published information on the population characteristics of *H. roei* in W. A.

In the late 1960's a small fishery for *H. roei* was begun along the central west coast of Western Australia. *H. roei* is a small species with a maximum length of 12 cm, though few animals reach this size. The minimum legal size limits are 6 cm for amateurs and 7 cm for professionals. The species lives in shallow water with the populations concentrated at the seaward margins of intertidal rock platforms. The populations are easily accessible to amateur fishermen who collect on the shallow, intertidal platform where recruitment takes place (Keesing and Wells, 1989). It is of concern that over fishing and taking of small individuals, well below the legal size limit for amateurs, may affect recruitment potential in *H. roei*.

The present paper compares size frequency characteristics of *H. roei* made annually during the summer from 1983 to 1988 at an unfished site and a heavily fished site and uses the information to provide basic information about recruitment levels in the two populations. To examine the effect of over fishing on population size and structure an isolated natural population was completely removed and re-examined at two and four year intervals.

MATERIALS AND METHODS

Two intertidal platforms in the Perth metropolitan area were selected for the study; both are platforms used for other studies of *H. roei.* Waterman is a marine reserve, and has been since the mid 1960's, so abalone populations in the reserve are in a nearly undisturbed condition. The second platform, at Trigg, is 3 km south of Waterman and has been heavily fished for most of the period since the fishery began in the mid 1960's. Two sites were investigated for each platform.

The intertidal platforms are essentially horizontal at low tide level. Abalone populations are greatest in a zone 3 m or less in width along the seaward margin of the platforms. Most such zones are less than 10 m long, though some reach as much as 20 m in length. Transects parallel to the reef edge were randomly placed in the above zones and 20 0.5 m^2 quadrats were sampled at each of two sites at both Trigg and Waterman platforms. All abalone in each quadrat were counted and the first 200 measured *in situ.* Samples were made quarterly, when weather permitted, from January 1983 through January 1985 and continued annually during January until 1988.

To examine repopulation of abalone in an over collected area, a subtidal rock approximately 2 m in diameter adjacent to the platform at Waterman was totally cleared of *H. roei* in late March 1983. Total length of all individuals was measured with calipers. The rock was examined visually in November 1983 and March 1984. In March 1985 and March 1987 complete recensusing was undertaken.

RESULTS

Densities of *H. roei* in January over the six years examined are shown in Figure 1. Densities at Trigg were substantially lower than at Waterman in all years. The mean density at Trigg North was 35 and at Trigg West 49 m^{-2} compared to 123 at Waterman North and 158 m^{-2} at Waterman South. Densities fluctuated considerably from year to year on both platforms. At Waterman both the north and south sampling sites showed substantial annual variation with the population at Waterman South fluctuating by more than 70 m^{-2} from 1983 through 1987. The population at Waterman North was more stable, rising from 1983 through 1985, but then declining in 1986 and 1987 before increasing again in 1988. There was no consistent relationship between population densities at the two sites. Fluctuations at Trigg were lower in terms of absolute densities, but were nearly as great in terms of percentages.

Figure 2 shows density fluctuations on a quarterly basis over the period of October 1983 through January 1985. During the period of October 1983 through October 1984 population densities at Waterman varied without a consistent pattern being discernible; there was a rapid rise between October 1984 and January 1985. Thus the increase between the January 1984 and January 1985 samples on Figure 1 occurred in the last quarter sampled. The quarterly samples indicate that at Waterman there are substantial variations within a given year as well as between

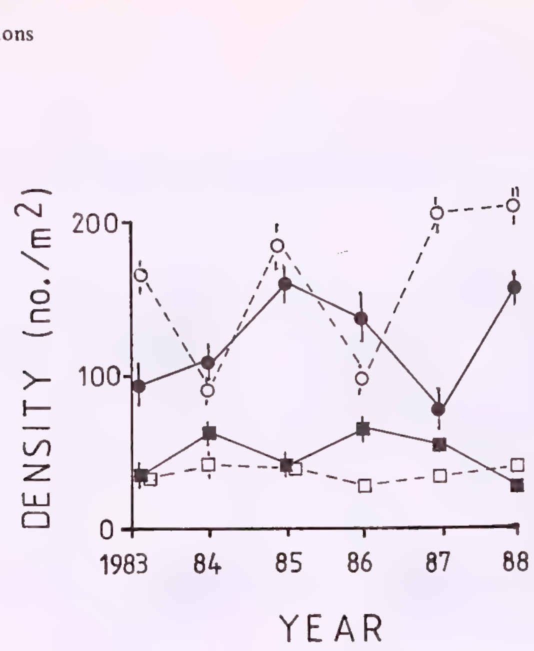

Figure 1. Densities of the abalone *Haliotis roei* measured annually during the summer (January) at four sites on intertidal platforms in the Perth metropolitan area, Western Australia. Means and one standard error are shown. ●——●, Waterman North; O——O, Waterman South; []——[], Trigg North; ■——■, Trigg West.

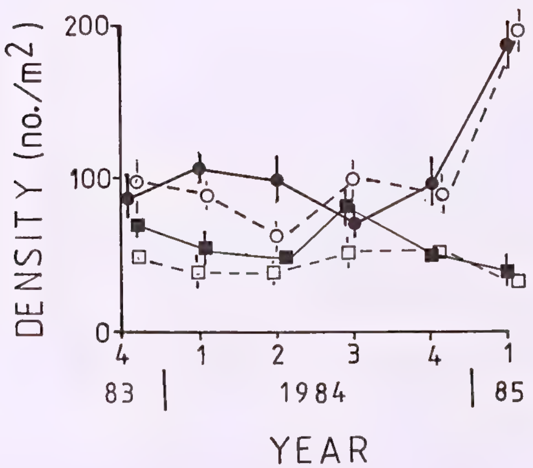

Figure 2. Densities of the abalone *Haliotis roei* measured quarterly from October 1983 through January 1985 at four sites on intertidal platforms in the Perth metropolitan area, Western Australia. Means and one standard error are shown. ●——●, Waterman North; O——O, Waterman South; []——[], Trigg North; ■——■, Trigg West.

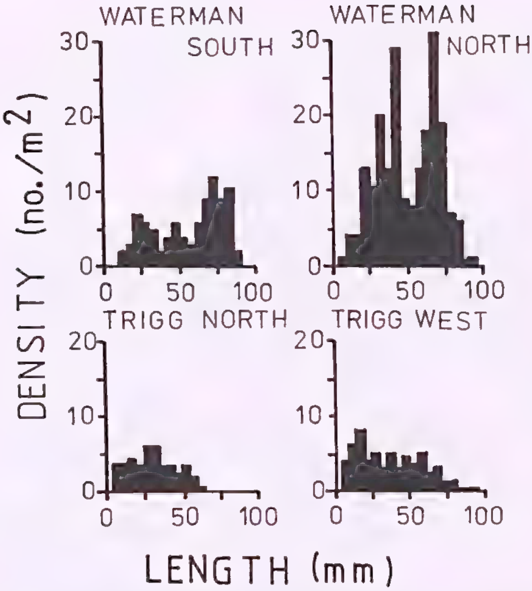

Figure 3. Size frequency characteristics of the abalone *Haliotis roei* in January 1984 at four sites on intertidal platforms at Waterman and Trigg in the Perth metropolitan area, Western Australia.

years. Densities at Trigg were relatively stable, with the exception of a rise at Trigg North in July 1984 followed by a decline in the final quarter of 1984.

Size frequency histograms for both Waterman North and Waterman South (Figure 3) show that in January 1984 substantial portions of both populations were individuals greater than the legal size of 60 mm. *H. roei* take two years to attain this size, after growing to 46 mm in the first year (Keesing and Wells, 1989). In the six sampling periods which could be conducted during the quarterly sampling, a mean of 47.5% of the animals at Waterman North and 53.0% of those at Waterman South were of legal size. The situation at Trigg (Figure 3) was considerably different, with very few animals of legal size being present on the platform. An average of only 17.6% of the abalone at Trigg West were of legal size during the periods sampled. This site is much less accessible to amateur fishermen than Trigg North, where only 2.6% of the population was of legal size. Density data show the comparison even more clearly. In the six summer samples made between 1983 and 1988 the density of legal size abalone at Trigg North was always <1 m^{-2}. At Trigg West there were 8 m^{-2} in 1983, but this figure declined consistently over the next five years to 3 m^{-2} by 1988.

Data from the rock clearing experiment are summarized in Table 1. A total of 761 abalone with a combined wet weight of 78.5 kg were collected in March 1983. The population was strongly skewed towards large individuals; 537 animals, or 70.5%, were in the 2+ age group, and most were probably several years old. Only 17.0% of the population was in the 0+ age class. Small individuals are the most easily missed and it is likely that some were in fact not collected. However, open spaces became available as the larger individuals were removed and they were occupied by small individuals on subsequent days which were then more easily collected. Because of the intensive collection by two divers over several days we believe that the low representation of 0+ individuals was real, and not a collecting artifact.

The rock was visited at irregular intervals over the next two years. Most observations were made in summer as water conditions made winter visits difficult. During the winter of 1983, and subsequent winters, increased wave action due to storms washed the sand off the base of the rock and created a direct link to an adjoining rock. The link was visible as late as November in each year but became sand covered during the summers. During the winter months large abalone (>60 mm) moved from the adjacent rock onto the experimental rock, thus obscuring somewhat the results presented on Table 1. In March 1985 a total of 294 *H. roei* was removed from the experimental rock. Of these 153 (52.0%) were 2+ animals from the adjacent rock. Only 141 (48.0%) were less than 2 years old. Some of these may have migrated from the adjoining rock during the winters, but alternatively small individuals may also have migrated to the adjoining rock. 90 of the young were 0+ and 51 were 1+ animals. In March 1987 293 abalone were removed from the experimental rock, 142 of which were 2+. Of the young 83 were 0+ and 68 were 1+.

Table 1. Age and size structure of *Haliotis roei* collected on a small rock at Waterman, Western Australia. Determination of ages is based on growth rates provided by Keesing and Wells (1989).

Age (years)	Size (mm)	1983 No.	1983 %	1985 No.	1985 %	1987 No.	1987 %
0+	<45	129	17.0	90	30.6	83	28.3
1+	45-65	95	12.5	51	17.4	68	23.2
2+	>65	537	70.5	153	52.0	142	48.5
Totals		761	100.0	294	100.0	293	100.0

DISCUSSION

Densities of *H. roei* on the platform at Trigg were shown to be consistently lower than those at Waterman, 3 km to the north. The platforms are similar in outward appearance, and there are no known physical, biological or chemical differences which suggest reasons for the differences in population levels. However Waterman is a fishery reserve, while Trigg was heavily fished prior to the implementation of temporary bans on the taking of abalone in the Perth metropolitan area in March 1982, and has been heavily fished in recent summers. Data presented here demonstrate that the population of abalone at Trigg had not recovered by the time the first samples were made in January 1983. Total bans on abalone collecting were in place during the summer of 1982-3 but seasonal closures during the winters has been the management procedure since that year. The data demonstrate that for the easily accessible site at Trigg North there has been no recovery of the *H. roei* population. Less than 1% is of legal size at any given time, and numbers of abalone >5 cm are also reduced by fishing pressure. At Trigg West densities of legal size abalone have declined steadily since 1983, even with more stringent management procedures and increased public awareness of the potential for overfishing.

H. roei in the Perth metropolitan area spawns over a period of several months from June through the remainder of the calendar year, but the majority of spawning is concentrated in the July to August period (Wells and Keesing, 1989). Young individuals first became numerous in our samples at a size of <15 mm in January in both years surveyed at Trigg. At this stage they were about six months old, and were thus no longer recruits to the population. Continued recruitment at Trigg demonstrates the resilience of the population despite the heavy fishing pressure on adults. The question is where the adults are that produce the larvae which recruit at Trigg. Wells and Keesing (1989) have shown that in an unfished population (Waterman) adults <60 mm contribute only 3.2% of the total fecundity of the population. Data presented here demonstrate that there are few, if any, adults on the top of the platform. *H. roei* are known to settle on the intertidal seaward margins of the platforms and migrate subtidally as they grow (Keesing and Wells, 1989). Thus it is possible that the intertidal populations at Trigg are receiving recruits spawned subtidally nearby. However the platform is undercut at Trigg North, and there are few subtidal abalone. Abalone 7 cm in length were collected seaward of the site at Trigg West for analysis of reproductive state (Wells and Keesing, 1989) from January 1983 through December 1984. During this time it became increasingly difficult to collect 30 abalone monthly for the gonad analyses, and by the end of 1984 there were few reproductively mature abalone in the subtidal areas. The subtidal population has not recovered since the 1985, suggesting that *H. roei* on the intertidal platform at Trigg is being replenished from adjacent platforms. This is in contrast to the finding by Prince *et al.* (1987) that recruitment in *H. rubra* is a result of spawning by females within a restricted local area.

The continued recruitment at Trigg and the results of the rock clearing in the Waterman reserve suggest that populations of *H. roei* depleted through overfishing can be replenished by reproduction occurring on other platforms. Such recovery, however, is at best slow. After two years recovery of the *H. roei* population on the cleared rock due to the settlement of young was only 18.5% of what the population had been before the removal. In the following two years the recovery was only 19.5%, suggesting it would take at least ten years before the population recovered fully. This is probably an underestimate in that for each of the three years surveyed the 0+ group had more individuals than the 1+ group, presumably as a result of mortality. Alternatively a good settlement year could produce substantial numbers of recruits, which would rebuild the population more quickly. *H. roei* in the Perth area are primarily drift algal feeders, but also rasp macroalgae off the rock surface (Wells and Keesing, 1989). It is possible that if catastrophic removal of abalone occurred, such as through overfishing, the algal composition on the platform could alter before the population is re-established so that less preferred algal species are dominant and the abalone population does not recover. This possibility has not yet been addressed.

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